Dynamical T-S analysis of Mediterranean Sea water masses

Emil V. STANEV* and Jean-Marie BECKERS**

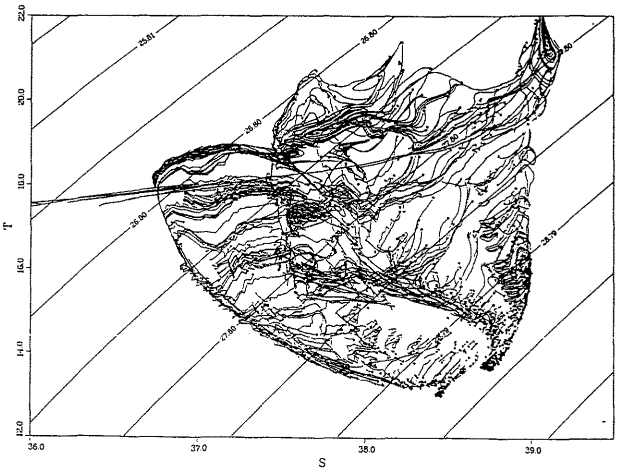
*Department of Meteorology and Geophysics, University of Sofia (Bulgaria)
**National Fund of Scientific Research, GHER University of Liège (Belgium)

T-S analysis was widely applied to study the water masses in the Mediterranean Sea. In the pioneering work of Wüst (1960), the efficiency of the core method to investigate intermediate and deep circulation was manifested. However, classical T-S analysis does not incorporate any local or remote physical information concerning the displacements of the particles in T-S space. This can be easily understood, since no such information existed in that time when the T-S analysis was developed. At present, numerical models provide us with a valuable information which can be used to increase substantially the understanding that can be obtained from the T-S analysis.

In the analysis proposed in the present paper the hydrological data are used to initialise a numerical model which we use as a tool to define the velocity field. Further, the displacement of Lagrangian particles in the T-S space is analysed in order to find some general properties of the water masses formation and mixing along trajectories.

Based on Levitus' (1982) data set, a combination of robust diagnostic and fully prognostic techniques is used to evaluate for the Mediterranean Sea a climatology consistent with the physics of the Princeton OGCM. Model experiments are carried out with 28 levels and with a horizontal resolution of $\Delta\lambda = 1/3$, $\Delta\phi = 1/4$. The model is forced mechanically by wind stress taken from Hellerman and Rosenstein's (1983) data. Sea surface temperature and salinity are prescribed from Levitus' (1982) data. Exchange flows in the Strait of Gibraltar are explicitly prescribed with 1.5 10^6 m^3s^{-1} each. At the most, model adjusted salinities and temperatures depart from Levitus' initial data by 0.02 and 0.05°C in deep layers and by 0.1 and 1°C in the pycnocline. The simulated circulation is generally cyclonic. Velocity profiles reveal a subsurface jet at about 50m advecting Atlantic water eastwards. With increasing depth a reversal of zonal flow is simulated with a core at about 300m advecting Levantine Intermediate Water westwards. The model simulated T-S indices for the entire Medirranean Sea does not deviate substantially from the initial ones. For about 5% of the grid points Lagrangian displacement $\vec{x}$ is calculated from $\vec{x} = \vec{v}(\vec{x})$, see the figure, where velocity $\vec{v}$ is taken from the model data. The trajectories illustrate the preferable mixing patterns. Their analysis can be used to define the general processes of water masses formation and transformation what is the topic of this paper.

TRAJECTORIES IN T-S SPACE



REFERENCES

Hellerman S. and M. Rosenstein, 1983. Normal monthly wind stress over the World Ocean with error estimates. Journal of Physical Oceanography, 17, 158-163.

Levitus S., 1982. Climatological atlas of the world ocean. NOAA Prof.Paper. 13, 173pp., 17 microfiche, U. S. Govt. Printing office, Washington, DC.

Wüst G., 1960. Die Tiefenzirkulation des Mittelländischen Meeres in der Kernschichten des Zwischen und Tiefenwassers. Deut. Hydrogr. Zeit., 13, 3, 105-131.

Bio-Optical Variability in the Western Mediterranean

Robert A. ARNONE and Paul E. LA VIOLETTE

Naval Oceanographic and Atmospheric Research Laboratory, Stennis Space Center, MS, 39527 (U.S.A.)

Ocean color satellite data were used to investigate the monthly and spatial variability of phytoplankton pigment concentration and diffuse attenuation coefficient (k(490)) in the western Mediterranean Sea. Coastal Zone Color Scanner (CZCS) composite products (Feldman, 1989) for 1979-1980 were used to define the bio-optical variabilities in specific regions: the Ligurian Sea, Gulf of Lion, Balearic Sea, Central Algerian Basin, Algerian Current, and Alboran Sea.

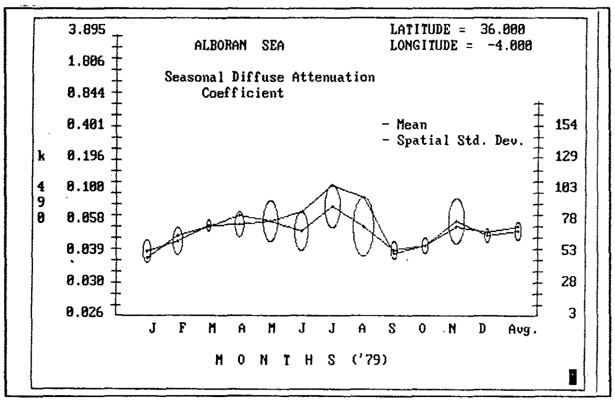
The development of mesoscale ocean features and bio-optical evolution of water masses in these regions were characterized by monthly CZCS imagery. The imagery were averaged into 20 km pixel resolution and processed by standard atmospheric removal methods (Gordon and Clark, 1980). Ratio algorithms (Gordon and Clark, 1980; Austin and Petzold, 1980) applied to these results produced monthly mean and standard deviation bio-optical properties. Although ocean color represents only the integrated upper ocean (approximately the first attenuation length), the surface distributions depict the bio-optical climate of the sea (since stronger biological responses occur near the surface).

The composite monthly results show that the evolution of biological and optical properties in the western Mediterranean interacts strongly with the regional surface circulation. The results also indicate a biological response to meteorological forcing of the Mistral. The biological repercussions of coastal processes and its effects on the large scale biological budget of the sea is also evidenced.

The mean phytoplankton distribution for the entire Western Mediterranean indicates that the lowest concentrations occur in September. High concentrations vary seasonally from region to region. The Alboran Sea has the highest concentrations as well as the strongest seasonal variability (the strongest bloom occurring in July (1 mg/m3) with a secondary bloom in November) (figure). The Gulf of Lion also shows a bi-modal pigment seasonal distribution, with maximums (0.4 mg/m3) occurring in April and December. The central Algerian Basin maintains a weak seasonally stationary phytoplankton distribution (<0.1 mg/m3). As a result of the regional ocean dynamics, the Algerian current exhibits significant spatial variability with elevated concentrations occurring in June.

The monthly standard deviation of the bio-optical properties is similarly associated with the surface circulation. High standard deviations occur in energetic areas such as ocean fronts and upwelling regions do to the response of phytoplankton to the rapidly changing physical processes. Thus, the locations of high monthly bio-optical changes are coincident with positions of fronts and eddies within the several ocean basins and within coastal areas.

This study illustrates the biological seasonal evolution of surface waters in the Western Mediterranean. This biological climate may be used to assess the amplitude and frequencies of seasonal biological productivity (Lohrenz et al, 1989). The study confirms a direct coupling of the overall general circulation and the surface biological phytoplankton distribution. CZCS imagery indicates that elevated phytoplankton concentrations associated with coastal processes extends well offshore and may have an impact on the regional water mass biological character.



References:

Austin, R.W. and T. J. Petzold, "The determination of the diffuse attenuation coefficient of sea water using the coastal zone color scanner" in *Oceanography from Space*, J.F.R. Gower, ed., Plenum, New York, 239 (1981)

Feldman, G. "Ocean Color" EOS 70:23 p634 (1989)

Gordon, H. R. and D. K. Clark, "Atmospheric effects in the remote sensing of phytoplankton pigments", Boundary-Layer Meteorology 18, 229-313 (1980)

Gordon, H. R. and D. K. Clark, "Clear water Radiances for atmospheric correction of coastal zone color scanner imagery," Appl. Optics, 20:24, 4175-4180

Lohrenz, S. E., R. A. Arnone, D. A. Wiesenburg, and I. P. DePalma, Satellite detection of transient enhanced primary production in the western Mediterranean Sea, Nature 335(6187) 245-247, 1988.